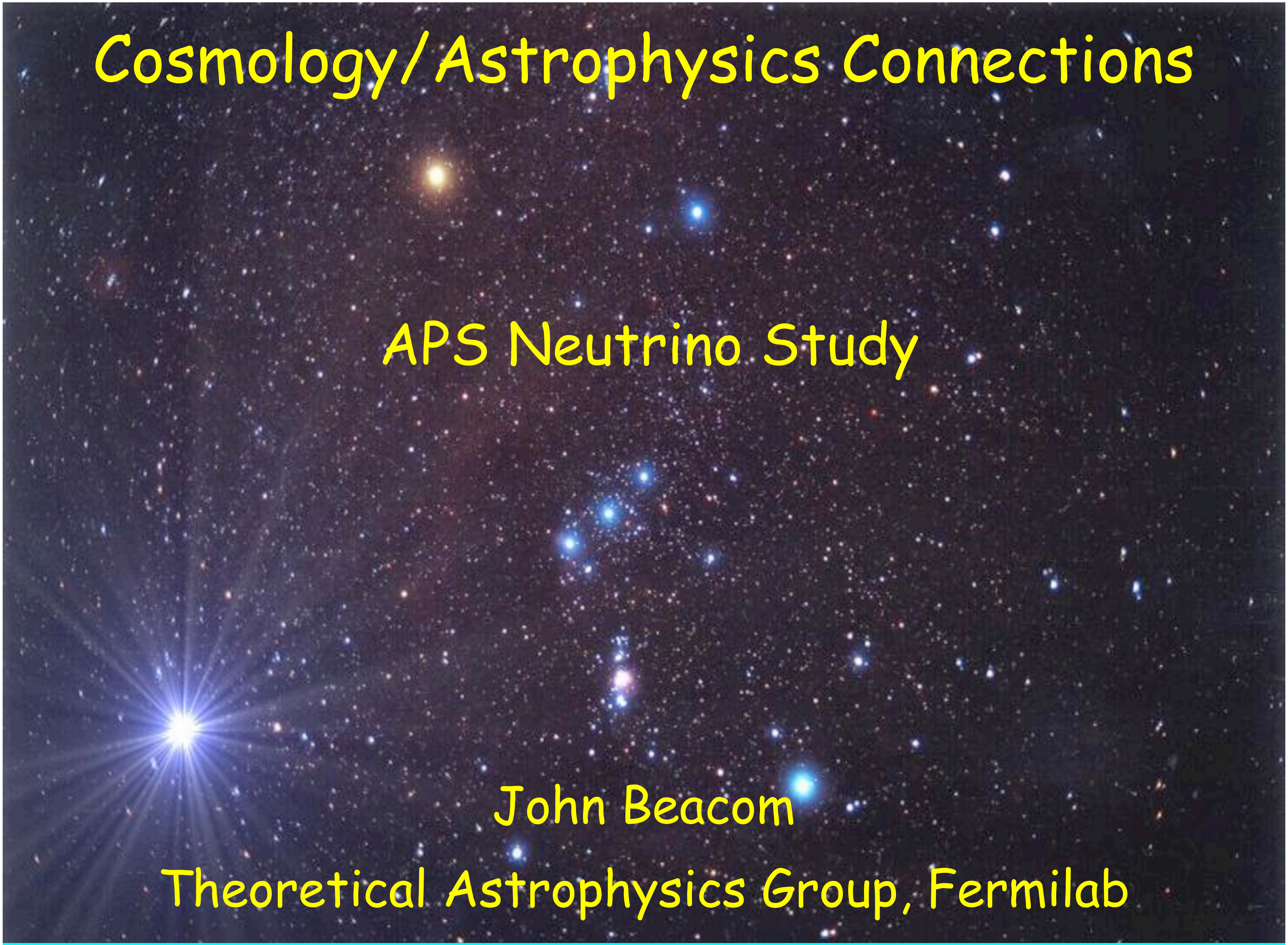


Cosmology/Astrophysics Connections

APS Neutrino Study

John Beacom

Theoretical Astrophysics Group, Fermilab

The Forces of Darkness

and

The Forces of Weakness

One Big Question

Are improved measurements of neutrino mixing parameters important for astrophysics/cosmology?

Conventional wisdom would be: *Of course not!*

Why not? Survey says…

Neutrinos, schmeutrinos

Cosmology, cosmetology

Astrophysics/Cosmology ok to factors ~ 10

Neutrino mixing irrelevant for cosmology, ρ_ν

Can't detect astrophysical neutrinos

Short Rebuttal

- We have a reasonable working picture of the neutrino sector, but it is not complete

- Precision cosmology is here, with much more detailed cosmological/astrophysical data on the way

- Detection of neutrinos from various astrophysical sources is very promising

- Connections between astrophysics/cosmology and fundamental physics are now *inescapable*

Key Observational Results

Cosmological

- Big-bang nucleosynthesis consistency
- Neutrino hot dark matter models ruled out

Astrophysical

- Neutrinos from SN 1987A observed
- The solution of the solar neutrino problem

Fundamental

- Neutrinos have mass and mixing
- Non-discovery of all manner of exotica

Participants, Page 1

Working Group Leaders

Steve Barwick (UC Irvine)

John Beacom (Fermilab)

Participants at Argonne meeting:

Baha Balantekin
Nicole Bell
Dick Boyd
Mu-Chun Chen
Vince Cianciolo
Mike Dragowsky
Ernie Henley
Albrecht Karle
Teppei Katori
Boris Kayser
Paul Langacker
John LoSecco
Doug McKay
Paul Nienaber
Keith Olive
Tatsu Takeuchi
Jon Thaler
Neil Weiner

Participants, Page 2

New participants since Argonne meeting:

Gianfranco Bertone	Cecilia Lunardini	Sylvia Pascoli
Lali Chatterjee	Misha Medvedev	Rob Plunkett
Scott Dodelson	Peter Meszaros	Georg Raffelt
Jonathan Feng	Tony Mezzacappa	Todor Stanev
George Fuller	Irina Mocioiu	Mark Vagins
Manoj Kaplinghat	Hitoshi Murayama	Terry Walker
John Learned	Sergio Palomares	Bing-Lin Young

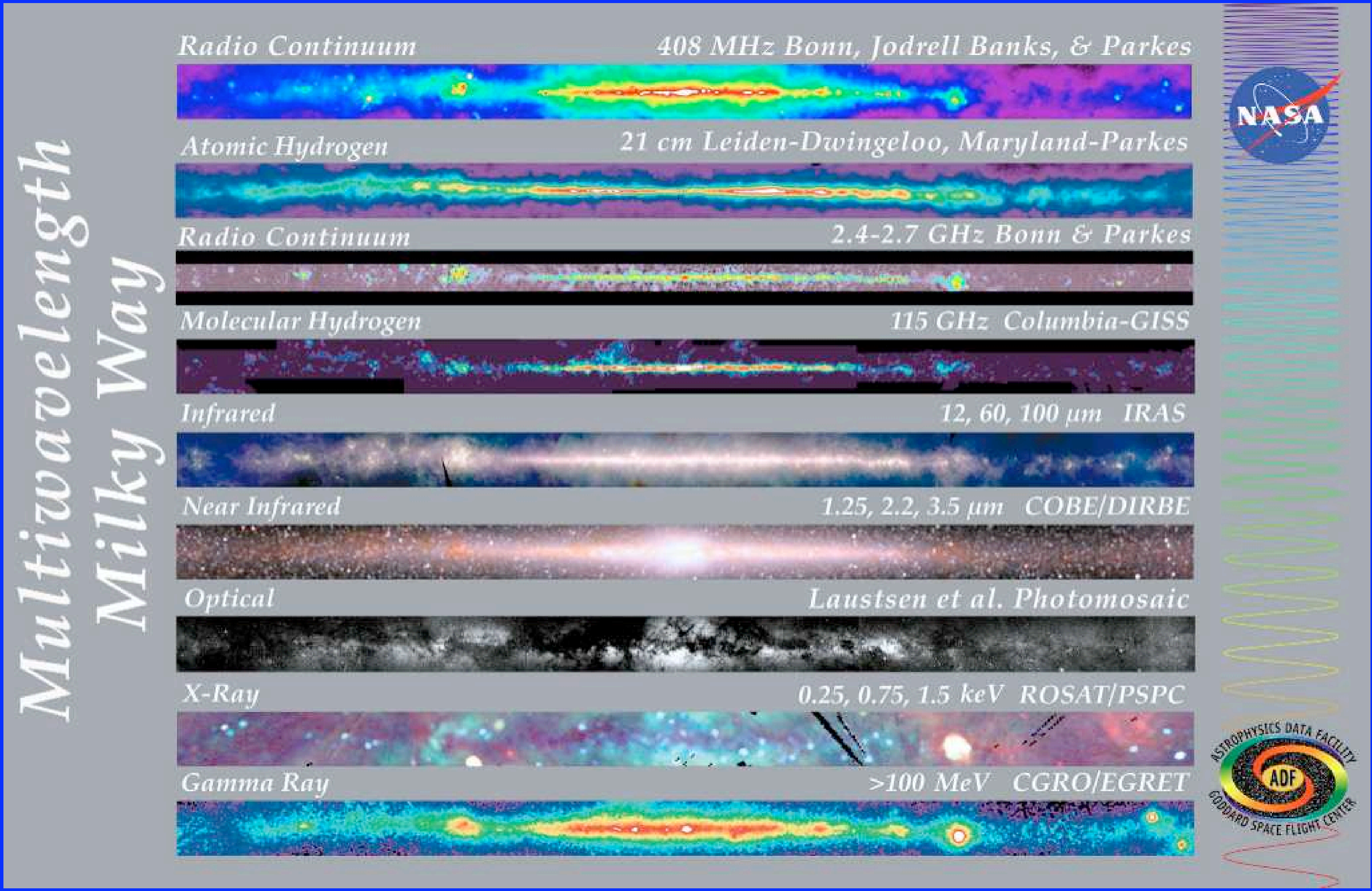
Working Group Assignments

Our goal is to produce a 30-40 page document that makes a clear and compelling case for the importance of new experiments and observations that (a) provide unique tests of the properties of neutrinos, and/or (b) use neutrinos as a new probe of the universe and its evolving contents. We also want to build on the recent successes in this field, and to highlight the inescapable connections between progress in astrophysics/cosmology and particle/nuclear physics.

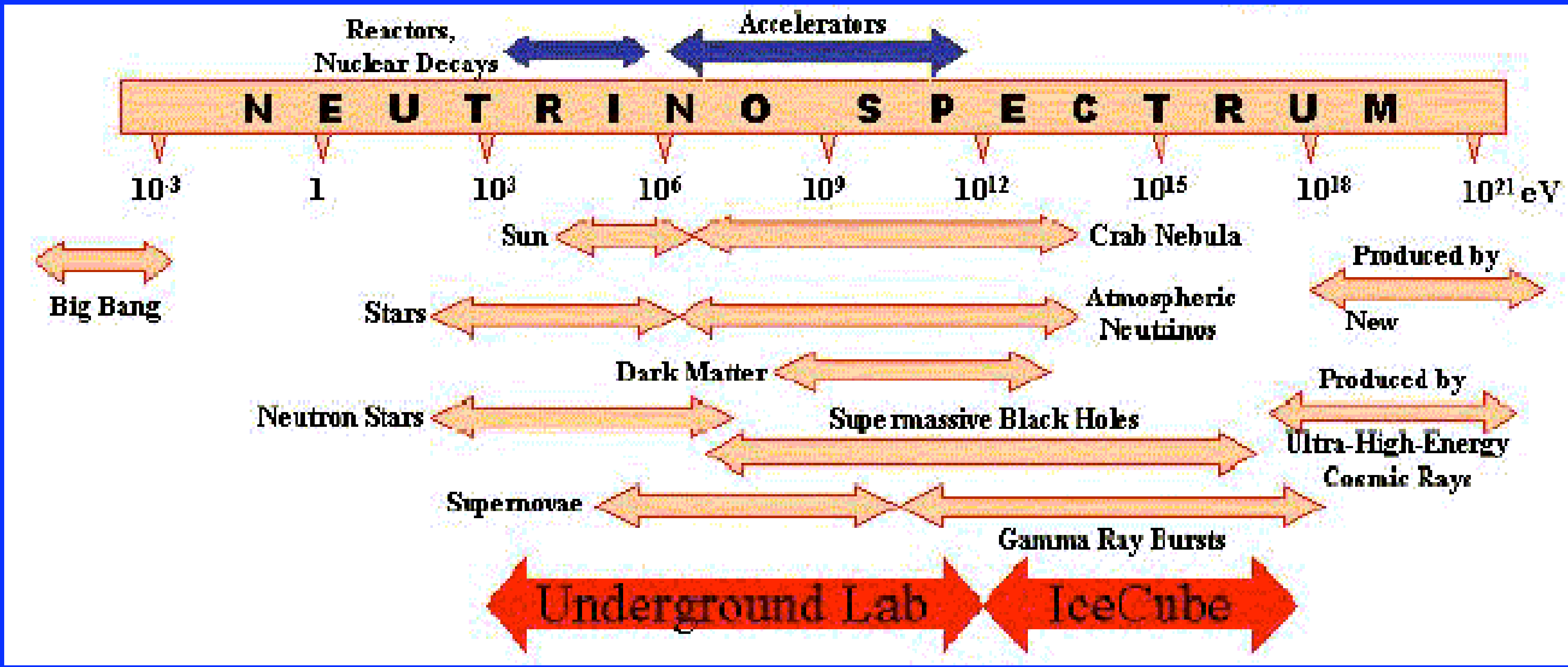
Our WG identified 12 key opportunities and found 12 volunteers to write about 3 pages each, to be due by 1 May 2004. We will merge and refine them, and title the final product

Steal This Proposal

Photon Windows

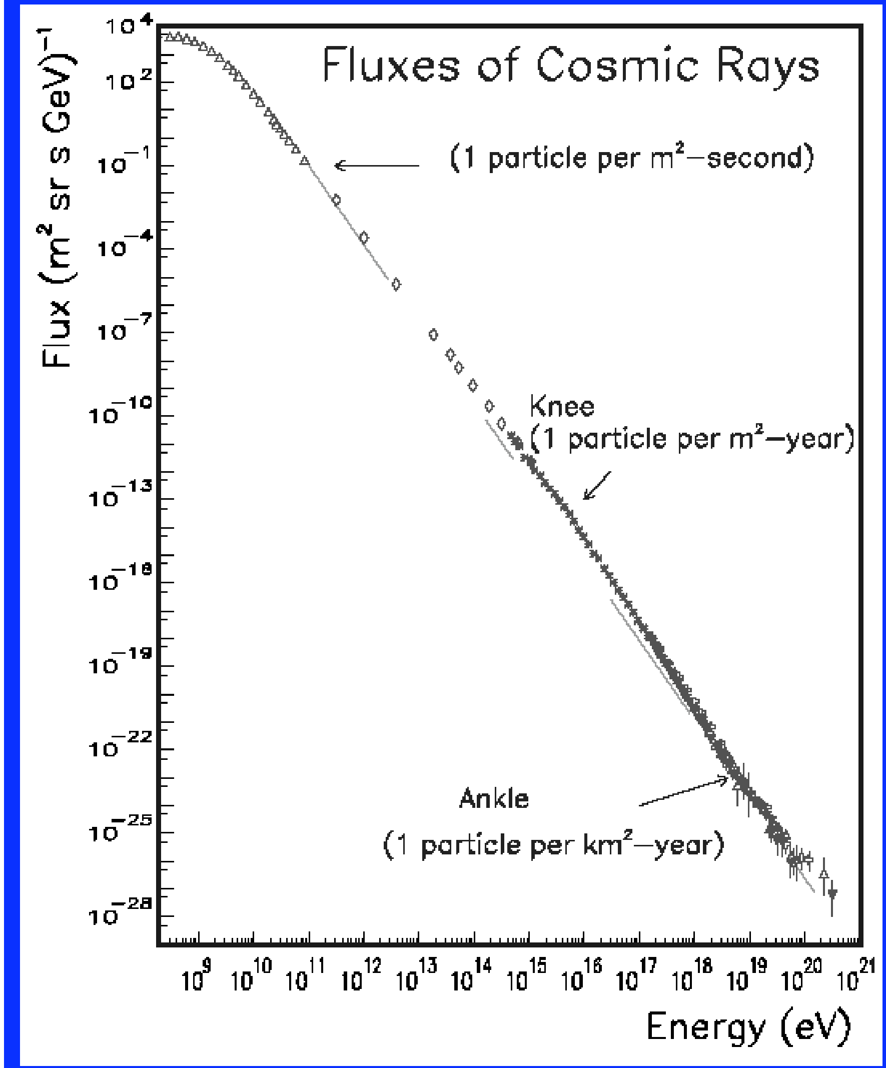


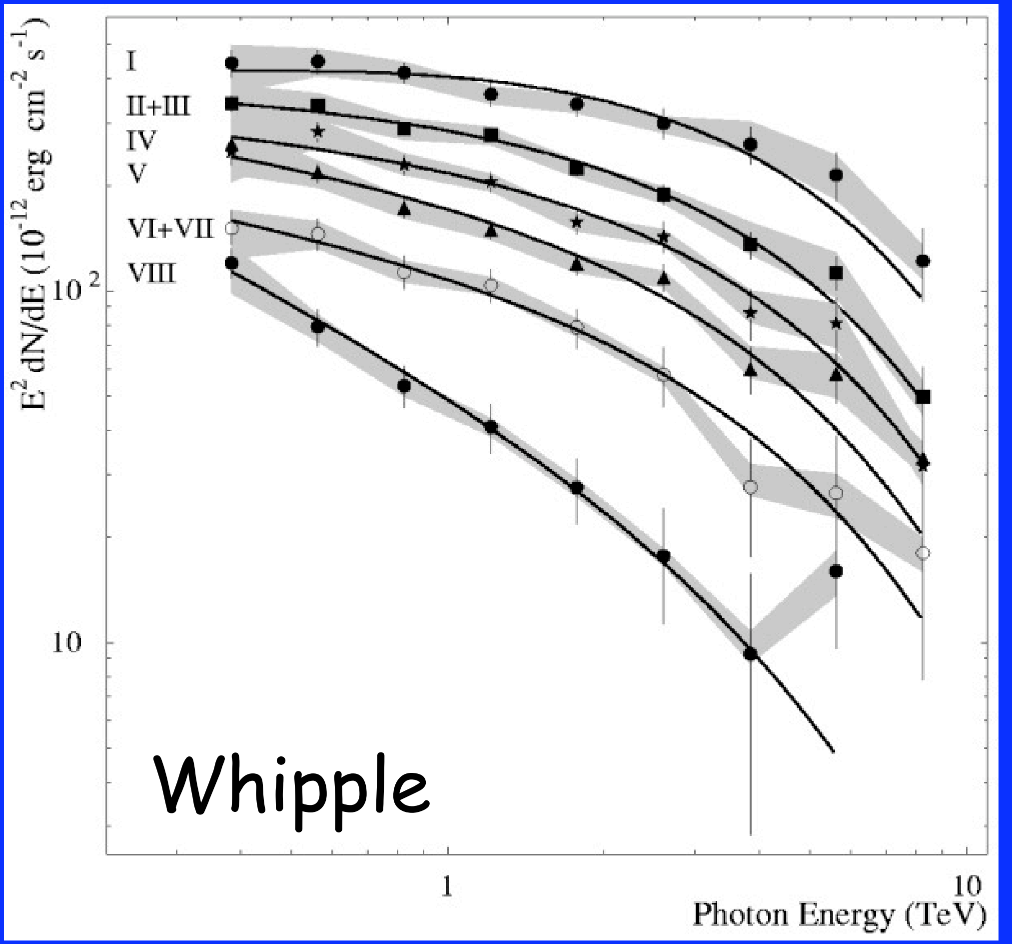
Neutrino Windows



Neutrino Facilities Assessment Committee, NAS (2002)

High Energy Messengers



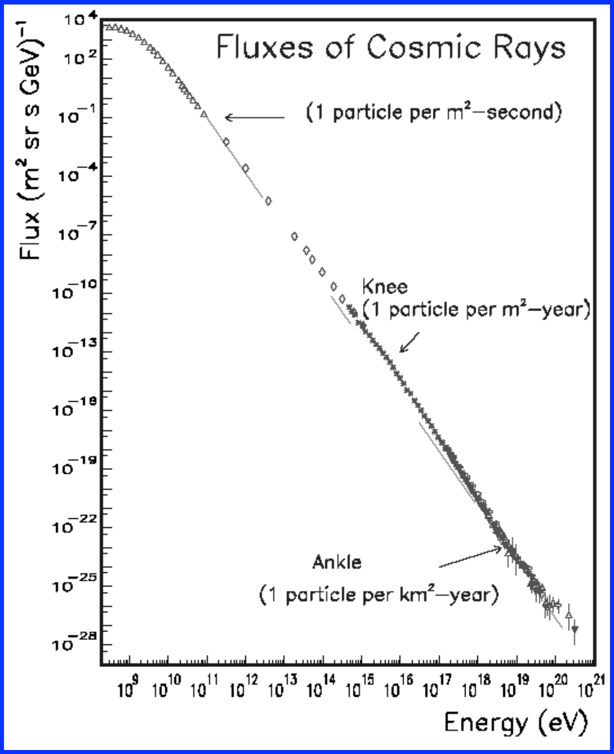


F. Krennrich et al., ApJ 575, L9 (2002)

Protons (diffuse)

Photons (Markarian 421)

1. Origin and Nature of the Cosmic Rays



• ***Opportunity:***

p, γ, ν fluxes connected

• ***Potential Importance:***

Probe highest energy sources

• ***Primary Experiments:***

Cosmic ray arrays, GZK neutrino detectors

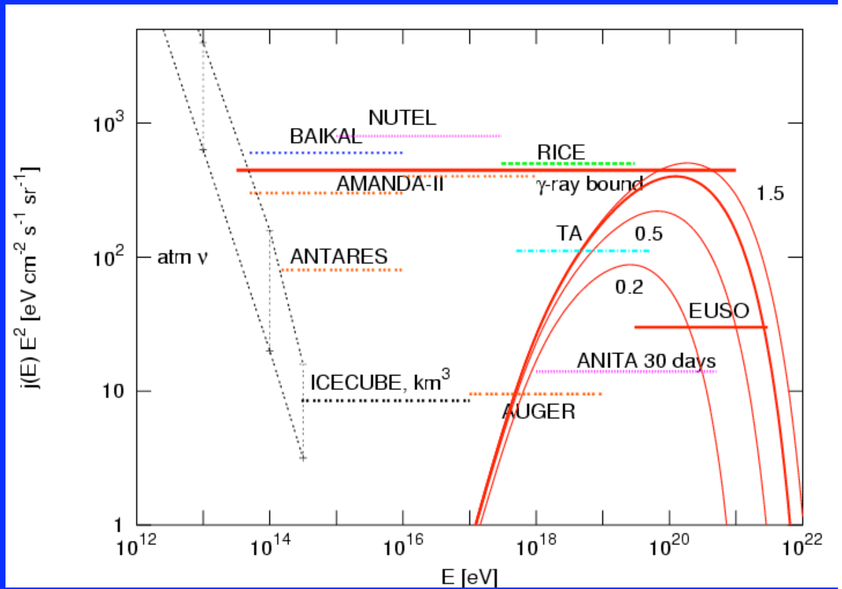
• ***Lead Writer:***

Todor Stanev (Bartol)

2. New Physics Above the TeV Scale

• ***Opportunity:***

GZK flux bounded from below



• ***Potential Importance:***

$\sigma(\nu + N)$ at energy frontier

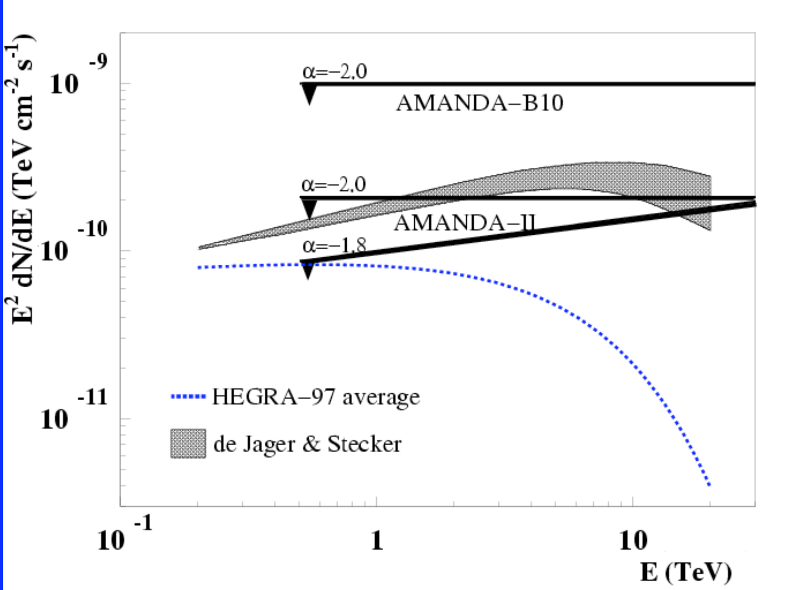
• ***Primary Experiments:***

GZK neutrino detectors

• ***Lead Writer:***

Doug McKay (Kansas)

3. Probes of HE Astrophysical Sources



• ***Opportunity:***

p, γ, ν fluxes connected

• ***Potential Importance:***

New understanding of sources

• ***Primary Experiments:***

IceCube-like, gamma-ray telescopes

• ***Lead Writer:***

Peter Meszaros (Penn State)

4. Dark Matter Searches

• ***Opportunity:***
Combined accelerator, direct, and indirect bounds

• ***Potential Importance:***
Nature of the particle dark matter

• ***Primary Experiments:***
IceCube-like

• ***Lead Writer:***
Jonathan Feng (UC Irvine)

5. Probes of Supernova Astrophysics

•***Opportunity:***

Neutrino data would help complete the SN puzzle

•***Potential Importance:***

Explosion mechanism, nuclear equation of state

•***Primary Experiments:***

Supernova detection, numerical modeling

•***Lead Writer:***

Tony Mezzacappa (Oak Ridge)

6. Supernova Tests of Particle Physics

•***Opportunity:***

SN 1987A data was crucial to testing new physics

•***Potential Importance:***

Much stronger limits are possible in principle

•***Primary Experiments:***

Supernova detection, nucleosynthesis studies

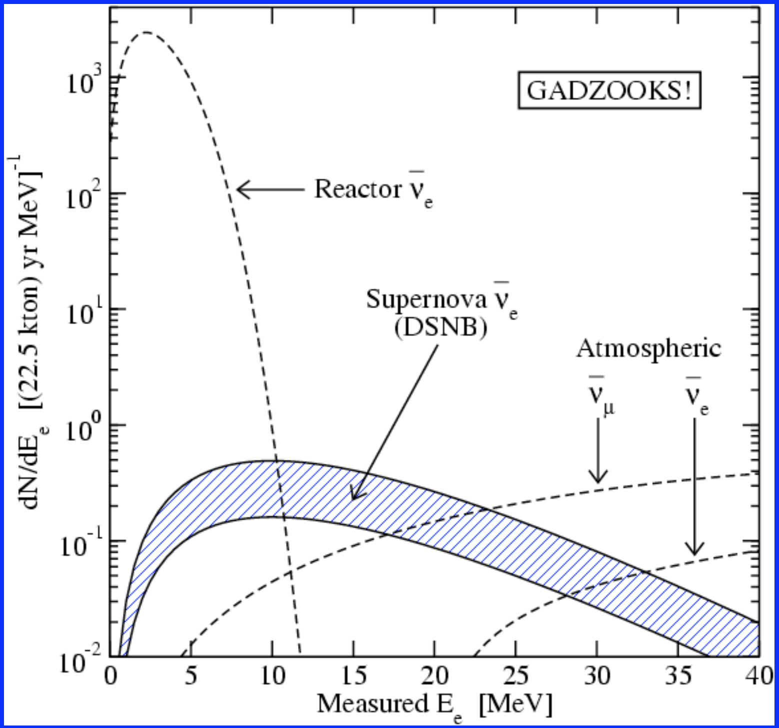
•***Lead Writer:***

George Fuller (UC San Diego)

7. Diffuse Supernova Neutrino Background

Opportunity:

SK with Gd could detect soon



Potential Importance:

Tests supernova models, rate

Primary Experiments:

SK with Gd, UNO/HK

Lead Writer:

Terry Walker (Ohio State)

8. Neutrino-Nucleus Cross Sections

• ***Opportunity:***

Key to explosion, nucleosynthesis, and detection

• ***Potential Importance:***

Much improved understanding of supernovae

• ***Primary Experiments:***

Muon DAR neutrino sources, maybe beta beams

• ***Lead Writer:***

Vince Cianciolo (Oak Ridge)

9. Leptogenesis and the Baryon Asymmetry

•***Opportunity:***

Connects laboratory data to GUT scale physics

•***Potential Importance:***

Neutrino mass connected to baryon asymmetry

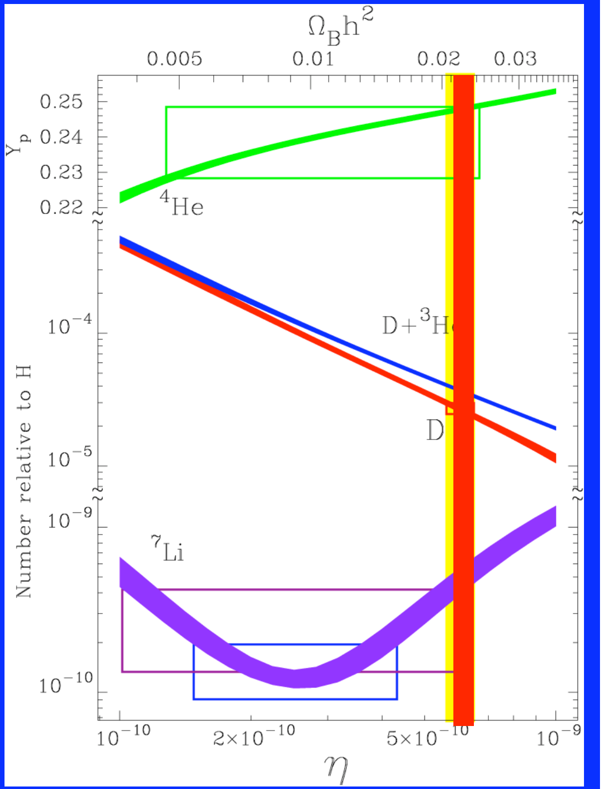
•***Primary Experiments:***

Other GUT scale probes, pencil and paper

•***Lead Writer:***

Hitoshi Murayama (UC Berkeley)

10. Precision Big Bang Nucleosynthesis



•***Opportunity:***

Qualitatively new data

•***Potential Importance:***

N_ν, baryon density

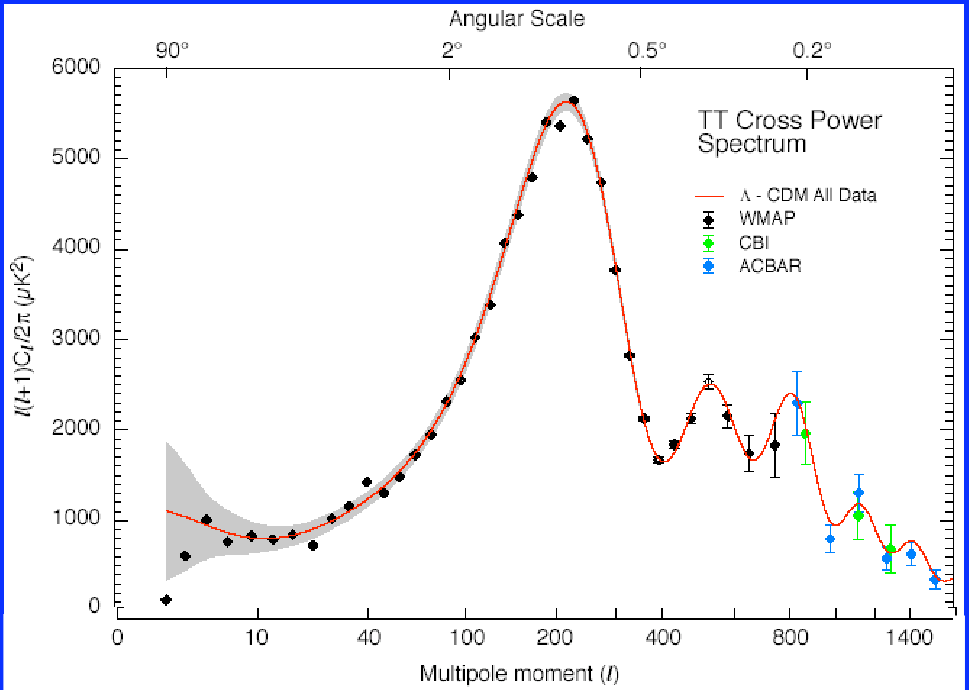
•***Primary Experiments:***

Quasar absorption lines, low-Z stars, CMB

•***Lead Writer:***

Keith Olive (Minnesota)

11. Precision Cosmic Microwave Background



- ***Opportunity:***
  Qualitatively new data

- ***Potential Importance:***
  very precise N_ν and m_ν

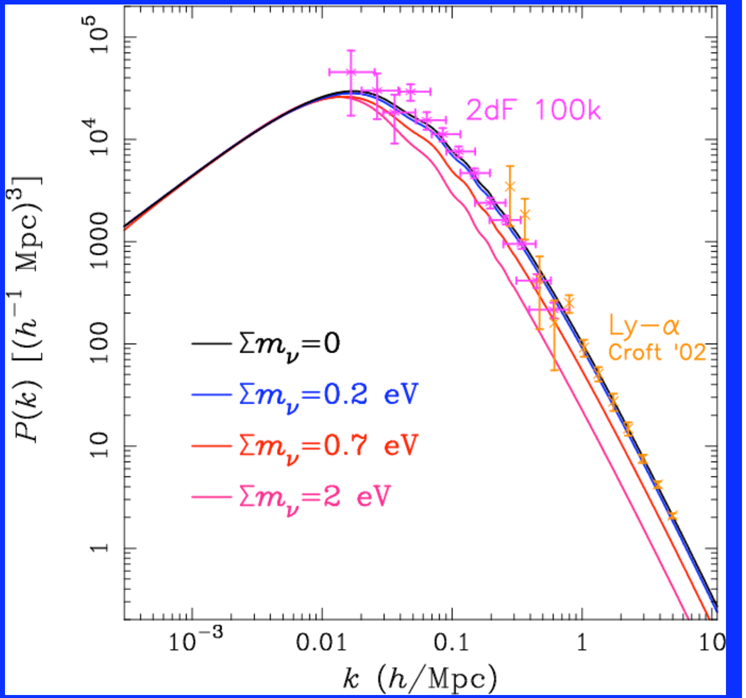
- ***Primary Experiments:***
  CMB satellites (polarization, high l)

- ***Lead Writer:***
  Manoj Kaplinghat (UC Davis)

12. Precision Large Scale Structure

•***Opportunity:***

Precision cosmology is here



•***Potential Importance:***

First and ultimate m_ν sensitivity

•***Primary Experiments:***

Galaxy, lensing, Lyman α surveys

•***Lead Writer:***

Scott Dodelson (Fermilab)

Aftertaste of Primordial Soup

- Cosmic *neutrino* background
  Note: harder to detect than CMB

- BBN, CMB can measure N_ν
  Depends on what the meaning of "nu" is

- Possible exception with large-scale structure
  Requires neutrino masses, precision cosmology

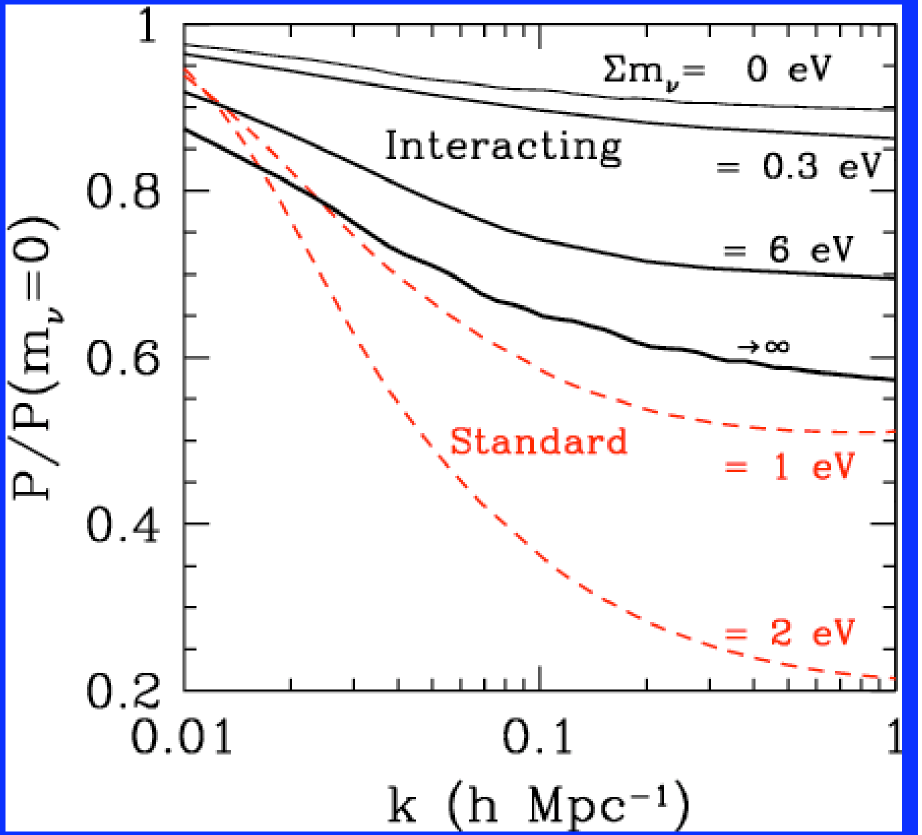
Neutrino mass, new physics, dark matter, etc

Neutrinoless Universe

Possibility:
Neutrino mass a few eV
But no relic neutrinos

$$\nu\bar{\nu} \rightarrow \phi\phi \text{ when } T \simeq m_\nu$$

$$m_\phi \ll m_\nu$$



Testable both directly and indirectly

Beacom, Bell, Dodelson, astro-ph/0404585

beta, double-beta mass tests

Astro/Cosmo Working Group

1. New experiments in neutrino astrophysics
2. Added value to cosmological observations
3. Key role of theory in making connections
4. Strong connections to other working groups and nuclear/particle laboratory data

Contact information:

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John Beacom beacom@fnal.gov

http://home.fnal.gov/~beacom/NuStudy/